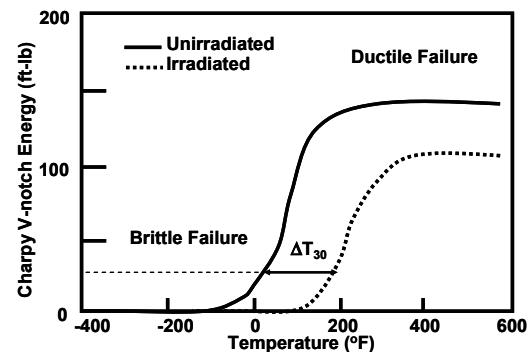


Characterization of the effect of Mn in reactor pressure vessel model alloys

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Introduction

The continued operation or lifetime extension of a number of nuclear power plants around the world requires an understanding of the damage imparted to the pressure vessel steel by irradiation. This damage results in a high number density of nanometer-sized copper rich precipitates and sub-nanometer defect-solute clusters, which are the cause of irradiation embrittlement.



Nanometer sized copper-manganese-nickel rich precipitates have been identified as the primary embrittling feature in reactor pressure vessel steels.

This poster presents results on a study of the initial precipitate evolution, and the effect of Mn on this evolution, in model Fe-Cu-Mn alloys.

Materials and Irradiations

Fe – 0.9% Cu

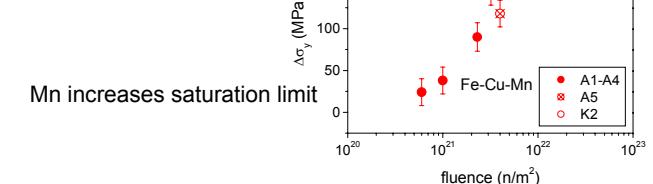
Fe – 0.9% Cu – 1.0% Mn

Neutron irradiation conditions used in this study. All irradiations were performed at $T = 290^\circ\text{C}$.

Irradiation Designation	neutron flux [$\phi (\text{n}/\text{m}^2 \cdot \text{s})$]	neutron fluence [$\phi t (\text{n}/\text{m}^2)$]
A1	7.0×10^{14}	6.0×10^{20}
A2	7.0×10^{14}	1.0×10^{21}
A3	7.0×10^{14}	2.3×10^{21}
A4	7.0×10^{14}	3.2×10^{21}
A5	5.0×10^{15}	4.0×10^{21}
K2	7.7×10^{15}	5.1×10^{22}

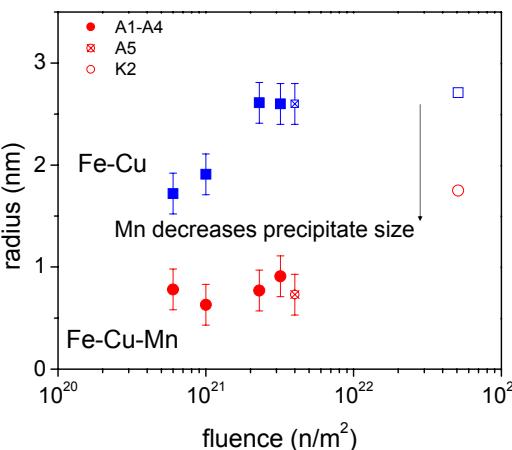
Results

change in yield strength with irradiation

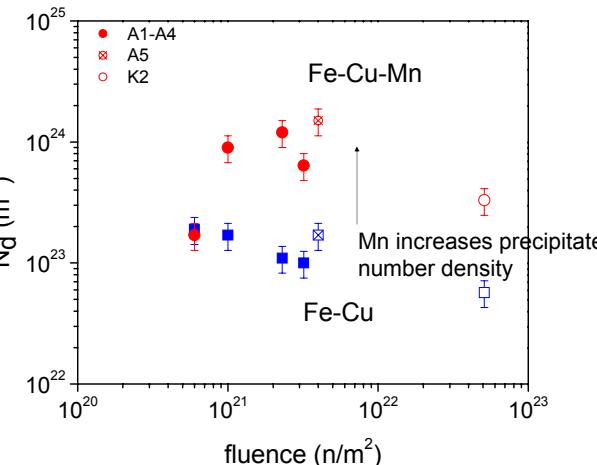


Small Angle Neutron Scattering (SANS) Results

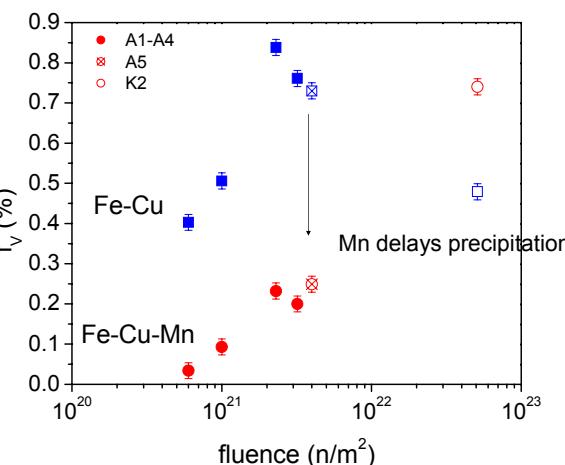
precipitate radius



precipitate number density

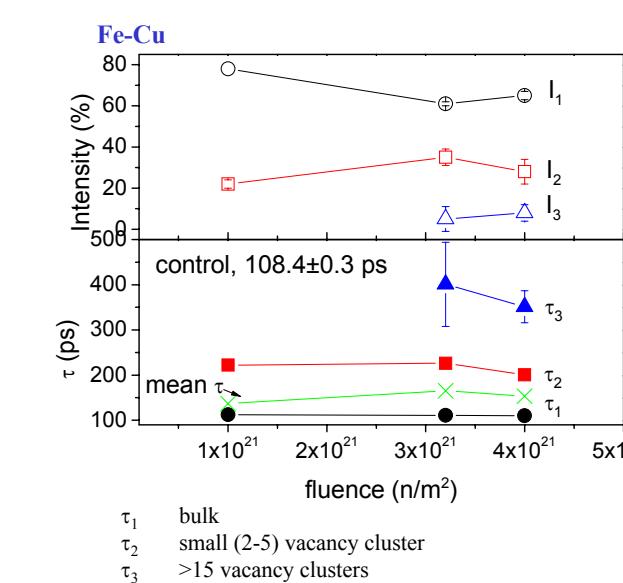


precipitate volume fraction

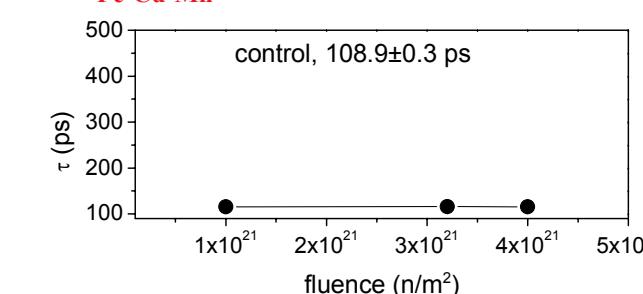


Positron Annihilation Spectroscopy (PAS) Results

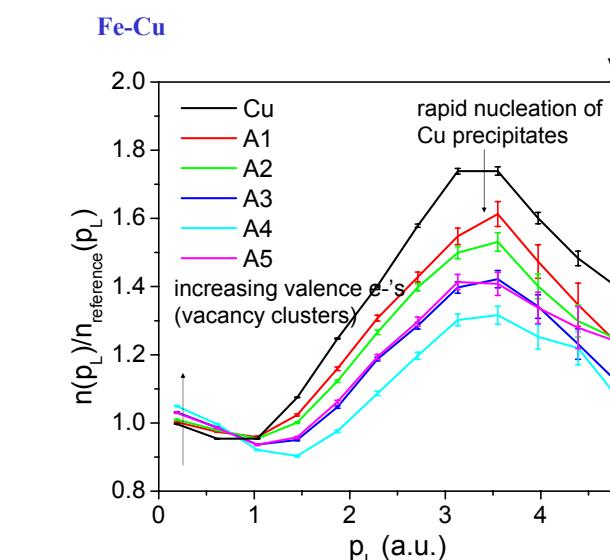
positron annihilation lifetime spectroscopy



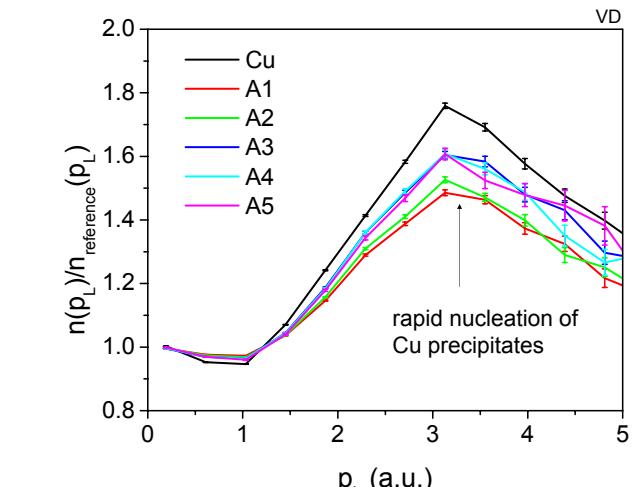
Fe-Cu-Mn



orbital electron momentum spectroscopy



Fe-Cu-Mn



Conclusions

- Mn decreases precipitate size, increases number density, and increases the saturation limit. This suggests Mn segregation at the iron matrix-Cu precipitate interface which reduces the interfacial energy and in turn the driving force for coarsening.
- Mn retards the precipitation kinetics at low fluence and inhibits large vacancy cluster formation. This suggests a strong Mn-vacancy interaction which reduces radiation enhanced diffusion.

This PAS and SANS study is consistent with a two feature embrittlement model of Cu-rich precipitates and vacancy solute cluster matrix features.

PAS magnetic polarization measurements confirm that the Cu precipitates are non-magnetic (data not presented).

Acknowledgments

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48 and partially supported by the US Nuclear Regulatory Commission.

For further information

Please contact glade1@lbl.gov. More information on positron techniques can be found at http://www-physics.llnl.gov/H_Div/Positrons/